Multiscale Heterogeneity Effects at Yucca Mountain

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RESEARCH OBJECTIVES

The objectives of this work are to characterize the multiscale variability of fracture and matrix hydrogeological properties, and to investigate the effects of multiscale heterogeneity on unsaturated flow and transport at Yucca Mountain, Nevada, the proposed site for the national high-level nuclear waste repository.

APPROACH

We developed a model for the Yucca Mountain unsaturated zone that represented complex heterogeneity at two different scales: (1) layer scale, corresponding to geological layering, and (2) local scale, corresponding to measurement scale. The horizontal variability of layer-scale properties was calibrated based on the available measurements collected in multiple deep boreholes. Vertical and horizontal correlation lengths were obtained using local-scale permeability and porosity data. Random fields of the three most sensitive hydrogeologic properties for a two-dimensional, vertical cross section of the site were generated by combining the average layer-scale matrix and fracture properties with local-scale perturbations (generated using a stochastic simulation method). Unsaturated water flow and conservative tracer transport were simulated throughout the cross section. The effects of multiscale heterogeneity were investigated by comparison to the homogeneous layer-wise rock properties used for mountain-scale flow and transport modeling at Yucca Mountain.

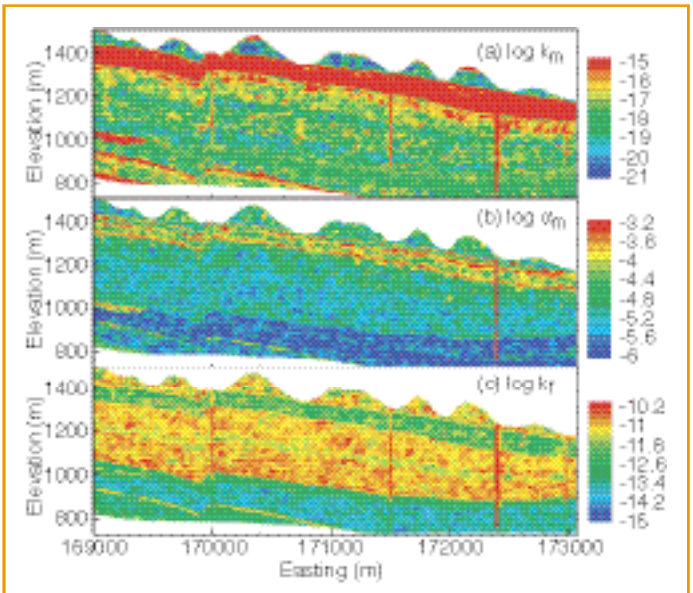

Figure 1. Random fields of matrix permeability, matrix α, and fracture permeability in the two-dimensional vertical cross section through borehole UZ-14, generated using multiscale heterogeneity

ACCOMPLISHMENTS

In addition to local-scale perturbations, the Yucca Mountain multiscale heterogeneity characterization captured the significant lateral and vertical variability in layer-scale matrix and fracture properties. This indicates that the multiscale heterogeneity of matrix and fracture properties has a considerable effect on unsaturated flow processes, leading to fast flow paths in fractures and the matrix. These paths shorten the travel time of a conservative tracer from a source (repository horizon) in the unsaturated zone to the water table. As a result, multiscale heterogeneity would seem to have a significant effect on local and global tracer-transport processes, especially for the early arrival of tracer mass. However, the effect on global transport is not significant at later times—for example, after 20% of tracer mass reaches the water table.

SIGNIFICANCE OF FINDINGS

This work has produced a useful approach for characterizing subsurface heterogeneity at different scales. It showed that multiscale heterogeneity has a significant effect on local and global flow and transport. Consequently, it improves and confirms our conceptual understanding of how rock heterogeneity affects nuclear waste disposal.

RELATED PUBLICATION

Zhou, Q., H.H. Liu, G.S. Bodvarsson, and C.M. Oldenburg, Flow and transport in unsaturated fractured rock: Effects of multiscale heterogeneity of hydrologic properties. Journal of Contaminant Hydrology, 60, 1–30, 2003.

ACKNOWLEDGMENTS

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